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BBC

RESEARCH DEPARTMENT REPORT

Band II f.m. sound broadcasting: the effects of a change to circular polarization

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Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

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SUMMARY

Measurements have been made to determine the effects on reception by fixed, portable and car radio receivers of a change from horizontal to circular polarization of the Band II f.m. transmissions.

For reception in the home, a change to circular polarization would be equivalent to a change of transmitter power of between +1 dB and -3 dB, depending on the type of receiving aerial in use. For reception with a car radio or with a portable receiver out of doors, it would be equivalent to an increase of transmitter power of from 5 dB to 7dB. These results are statistical averages and are subject to wide variations in individual cases, depending on local topography and the receiving aerial characteristics. They apply to the case where the total effective radiated power is the same for both horizontal and circular polarization.

1. INTRODUCTION

At the inception of the BBC Band II f.m. sound broadcasting service it was decided to radiate with horizontal polarization; this decision was made primarily with a view to reception by fixed installations in dwelling houses. In the ensuing period the fixed receiver has become less common and a substantial proportion of radio listening is now carried out with portable receivers both indoors and out and with car radios. Car radios and f.m. portable receivers generally employ vertical or near-vertical rod aerials which are situated comparatively close to ground level. They would therefore be expected to perform more efficiently on a vertically polarized than on a horizontally polarized signal, not only because the plane of polarization matched that of the aerial but also because, near the ground, the field strength of a vertically polarized wave is expected to fall less rapidly with decreasing height than that of a horizontally polarized wave.

The work described in this report was undertaken to determine what advantages or disadvantages would result, for various types of reception, from changing the polarization of Band II transmissions. In the U.K., a change to vertical polarization must be regarded as impracticable as this would necessitate changing existing fixed receiving aerials; therefore some form of mixed polarization would be necessary. The type of mixed polarization used in the tests was in fact circular, since it was considered that this would offer the greatest advantage if any change from the existing arrangement were adopted.

The comparisons were made on the assumption that the total effective radiated power (e.r.p.) would be the same on circular polarization as on horizontal polarization and the test conditions were arranged accordingly. This should be distinguished from the situation in the U.S.A. where (owing to the nature of the F.C.C. regulations) the case most frequently discussed is that where the change from horizontal polarization (h.p.) to circular polarization (c.p.) is accompanied by a 3dB increase in total e.r.p., i.e. the change is made by adding a vertically polarized (v.p.) component equal in magnitude to the existing h.p. component.

The tests were arranged to cover three different situations:—

(1) Reception in the home with portable receivers having built-in rod aerials, or with fixed receivers having built-in aerials or room aerials of comparable efficiency.

(2) Car radio reception.

(3) Reception with portable receivers in the open air.

It was thought that the effect on reception with fixed receivers having efficient outdoor or loft aerials was predictable as being a 3dB reduction of signal level but some measurements were made to confirm this assumption.

2. EXPERIMENTAL WORK

2.1. The Transmitters

Two Band II transmitters were installed at Kingswood Warren, Surrey, one radiating c.p. on a frequency of 90·2 MHz and the other radiating h.p. on 92·5 MHz. The total e.r.p. on each frequency was 50 W, i.e. 50 W h.p. on 92·5 MHz, but 25 W in the horizontal component and 25 W in the vertical component on 90·2 MHz. By making the total e.r.p. the same on each frequency – not the same in each h.p. component taken alone – we are investigating the case in which the total transmitter power and aerial aperture are fixed but the form of polarization is open to choice. The possibility of confusion between an advantage due to a change of polarization and one due to an increase of e.r.p. is thus avoided.

Both transmitters carried the BBC Radio 2 programme, obtained by reception of the London transmitter at Wrotham, and were modulated in accordance with BBC standard practice. Superimposed on the programme modulation were identifying tone bursts of approximately two seconds duration at one minute intervals, 300 Hz for the c.p. transmission and 1,200 Hz for the h.p. transmission. The aerial was designed to give an omnidirectional horizontal radiation pattern and appropriate checks were carried out to verify the circularity of the nominally c.p. transmission and the equality of the radiated power levels at the two frequencies.

In the following sections of this report, the horizontal and vertical components of the field produced by the h.p. and c.p. transmissions will be referred to as HP/H, CP/V etc. The two letters before the solidus define the transmission and the last letter defines the component of the field.

2.2. Home Reception

In the home reception tests, measurements were made by a team from Service Planning Section of Research Department at 21 houses within a radius of about 10 km from Kingswood Warren. These measurements included:–

(i) CP/H, CP/V, HP/H and HP/V field strength at 10 m above ground level (a.g.l.) immediately outside the house.

(ii) CP/H, CP/V, HP/H and HP/V field strength at 1 m above floor level at various points in the living rooms. The number of points investigated in each house varied from 5 to 8, depending on the size of the rooms. In two houses the rooms were on the first floor; in the remaining nineteen they were on the ground floor.

(iii) A subjective assessment of the ease with which a satisfactory position for a Band II portable receiver and its aerial could be found for each transmission. This assessment was expressed on a scale in which the c.p. transmission was rated with reference to the h.p. transmission as 'markedly worse,' 'slightly worse,' 'about the same,' 'slightly better' or 'markedly better.' Where there was a preferred plane for the receiving aerial rod, i.e. vertical or horizontal, this was recorded.

As a separate investigation, questionnaires were completed by a number of listeners, reporting on the grade of reception obtained in their homes from the test transmissions.

The results of the various tests are summarized below.

2.2.1. Measurements Outside Houses at 10 m a.g.l.

The levels of the four components of the fields at each site were normalized to the value of HP/H and Table 1 gives the averages of these normalized levels for all 21 sites.

TABLE 1

Relative Levels of Field Strength Outdoors at 10 m a.g.l. (Average of 21 Sites)

Component of field	Relative field strength, dB
HP/H	0
HP/V	–17·8
CP/H	– 2·8
CP/V	– 4·6

In order to evaluate more fully the results of a change of polarization to listeners with outdoor aerial systems, further data were extracted from these results.

(i) The ratio of CP/H to HP/H reached or exceeded at 10%, 50% and 90% of the sites investigated.

(ii) The ratio of either CP/V or CP/H, whichever was the greater, to HP/H reached or exceeded at 10%, 50% and 90% of sites.

This information is given in Table 2.

TABLE 2

Relative Levels of Field Strength Outdoors, dB

	10% value	50% value	90% value
Ratio $\frac{\text{CP/H}}{\text{HP/H}}$	0	–3	–5
Ratio $\frac{\text{CP/V or CP/H}}{\text{HP/H}}$	2	–2	–4

2.2.2. Measurements Inside Houses

The objective measurements made inside houses were processed as follows. First the median value of each component of the fields was determined for each house. These median values were then normalized to the median value of HP/H. Table 3 shows the averages of these normalized median values.

TABLE 3

Relative Levels of Field Strength Indoors (Average of 21 Sites)

Component of field	Relative field strength, dB
HP/H	0
HP/V	−5·3
CP/H	−0·2
CP/V	−3·7

The subjective assessment by the field team of the relative merits of the two transmissions for ease of positioning of a portable receiver has been expressed quantitatively by translating the descriptive terms into a numerical scale in which 'markedly worse' = −2, 'slightly worse' = −1 etc. up to 'markedly better' = +2. Thus a positive score denotes a preference for the c.p. over the h.p. transmission and a negative one the reverse.

In the majority of the houses investigated the subjective assessment was made in two living rooms but in some cases no meaningful subjective test was possible owing to inadequate field strength or to the presence of interference on one or both channels (some of the tests were made during periods of intense anticyclonic weather). Out of a total of 34 assessments, the average score was +0·26, i.e. a very slight preference for circular polarization.

The portable receiver used for the subjective tests had an extending rod aerial for v.h.f. reception that could be rotated in the vertical plane. Where there was a noticeable difference between the performance of the receiver with the rod vertical and with it horizontal this was recorded. Out of a total of 17 observations in which a preferred plane was found, taking both h.p. and c.p. transmission into account, the preference was for horizontal in 11 cases and for vertical in 6 cases.

2.2.3. Listener Questionnaires

Completed questionnaires were received from 22 sites, 11 of which were among the 21 investigated in the objective test programme described above. Six of these listeners observed with two Band II receivers and completed two questionnaires each, giving a total of 28 questionnaires. Of this total, 21 refer to portable receivers with built-in rod aerials loaned by Research Department for the tests, 5 to table model receivers with built-in or room aerials and 2 to table models with roof or loft aerials.

The period covered by the tests was marked by several spells of anticyclonic weather very favourable to long-distance v.h.f. propagation. Nine of the questionnaires mention interference on one or both channels which was either identified as, or could well have been, due to another transmission. The possibility of such interference introduces an uncontrolled factor into this section of the tests which indicates that all of these reception reports should be treated with some caution.

However, taking all the returned questionnaires, they did not reveal any systematic difference between the two types of polarization. For example, the answers to the question requiring an overall assessment of the relative merit of the two transmissions show 10 preferring h.p., 11 preferring c.p., and 7 regarding them as about the same. The numerical average score, arrived at by the procedure described earlier, is −0·05.

2.2.4. Discussion of Results of House Reception Tests

The relative levels of outdoor field strengths measured at 10 m a.g.l., shown in Table 1 and Table 2, are in good agreement with prediction bearing in mind that the effective power radiated in each of the CP/H and CP/V fields is half of that in the HP/H field. In other words, there is no evidence of a significant departure from the expected levels of −3 dB for both CP/H and CP/V (relative to HP/H), and the degree of cross polarization (−18 dB) is in general agreement with other work at v.h.f. using aerials at about 10 m above ground.

Table 2 also shows that a listener with an existing outdoor aerial arranged for reception of h.p. transmissions would not obtain any significant improvement for c.p. transmissions by rotating his aerial for v.p.

The overall result of a change to circular polarization for such listeners as far as signal level is concerned would be negligible for monophonic reception even at the limit of the nominal service area, defining this limit as the range at which the median field strength falls to 250 μV/m. For stereophonic reception, however, the change could produce a just-noticeable degradation of signal-to-noise ratio where the field strength was sufficiently low for receiver noise to be audible, i.e. about 2 mV/m or less.

The indoor figures, shown in Table 3, are rather surprising in that they show an HP/V component very little smaller than the CP/V component. This is presumably due to depolarization of the h.p. field by the structure, pipework etc. of the building. The implication of these results is that a change of polarization of the transmission from h.p. to c.p., or pre-

sumably to any intermediate stage between these limits, has a negligibly small effect on the polarization of the field within the average dwelling house. The mean results also show a tendency for the h.p. component to be somewhat larger than the v.p. component, even when c.p. is transmitted.

The subjective assessment by the measuring team is in very good agreement with the results shown in Table 3, i.e. a very slight preference for the c.p. as against the h.p. transmission and a slight preference for a horizontal receiving aerial as against a vertical aerial.

The subjective assessment in the listener questionnaires confirms the result of all the other measurements, namely that the transmitted polarization makes little difference on the average to reception within the house.

2.3. Car Radio Reception

2.3.1. Preliminary Tests

A limited series of subjective tests was carried out by three members of Research Department staff with portable receivers connected to their normal car aerials.

It is appreciated that such receivers are not likely to give as good an absolute standard of reception as a properly designed car radio, but this procedure was convenient and it was considered that the absolute performance would not invalidate comparisons made within the range of reasonable reception.

They reported on the relative merit of the two transmissions as judged during their daily journeys between home and Kingswood and generally driving around the district. Of these three reports, two indicated a preference for the c.p. transmission as giving a higher signal level and less deep fading, and one indicated similar performance on both transmissions. The two preferring c.p. referred to cars with front-wing-mounted vertical rod aerials and both covered chiefly the area between Kingswood and Reigate; the one with no preference involved a car with a vertical rod aerial clamped to the top of the rear window and covered the area between Kingswood and Caterham.

A further subjective listening test was made by a member of staff on a journey from Kingswood to Stoke Poges, a distance of 38 km, using a front-wing-mounted rod aerial on an Austin shooting brake with a commercial a.m./f.m. car radio receiver. This report stated that the h.p. transmission was unusable beyond 7 km from Kingswood whereas the c.p. transmission was 'quite acceptable to most motorists for casual listening' over most of the journey.

A report was also received from a receiver manufacturer who carried out a test with a vehicle in the area of Kingswood Warren. This stated that the performance on both transmissions was much the same. No further details of the test conditions or results were given.

In the next phase of the tests, it was considered that systematic measurements of the pick-up of car radio aerials while cruising should be able to give more quantitative information on the effects of the transmitted polarization. Accordingly, measurements of the r.f. signal voltage produced by vertical front-wing-mounted aerials on two vehicles, a Land Rover and an Austin A60 shooting brake, were made in three areas:—
(i) An open heathland road
(ii) A low-density housing area
(iii) A high-density housing area

The measurements were made by chart recordings at vehicle speeds of about 5 km/h (in order to record rapid flutter fading) over stretches of road about 50 m long spaced out in the area under investigation. Each journey was repeated in the opposite direction. The median signal level for each stretch of road was determined and the results are shown in Table 4 in terms of the average of the median signal levels of the c.p. signal relative to that of the h.p. signal, i.e. a positive ratio indicates a higher signal level from the c.p. transmission.

A full analysis of the recording charts was not made, but analysis of the recordings covering a few stretches of road indicated that the ratio of the values exceeded for 90% of the time was very similar to the ratio of the medians.

The tests described above indicated an overall advantage of c.p. relative to h.p. but they also showed considerable differences in results between one test and another that could have been due either to differences between vehicles or between different site conditions. Furthermore, the objective test results given in Table 4 showed that the type of terrain and the bearing of the transmitter relative to the heading of the vehicle could greatly affect the results obtained. It was therefore decided to carry out tests of a

TABLE 4

Averages of Median Signal Levels from Car Radio Aerial; Ratio of C.P. Signal to H.P. Signal, dB

	Land Rover		A60 Shooting Brake	
	Forward Run	Return Run	Forward Run	Return Run
Open Heath Road	−5·9	+3·5	+6·8	+5·3
Built-up Areas	−0·2	−0·8	−0·8	−0·1

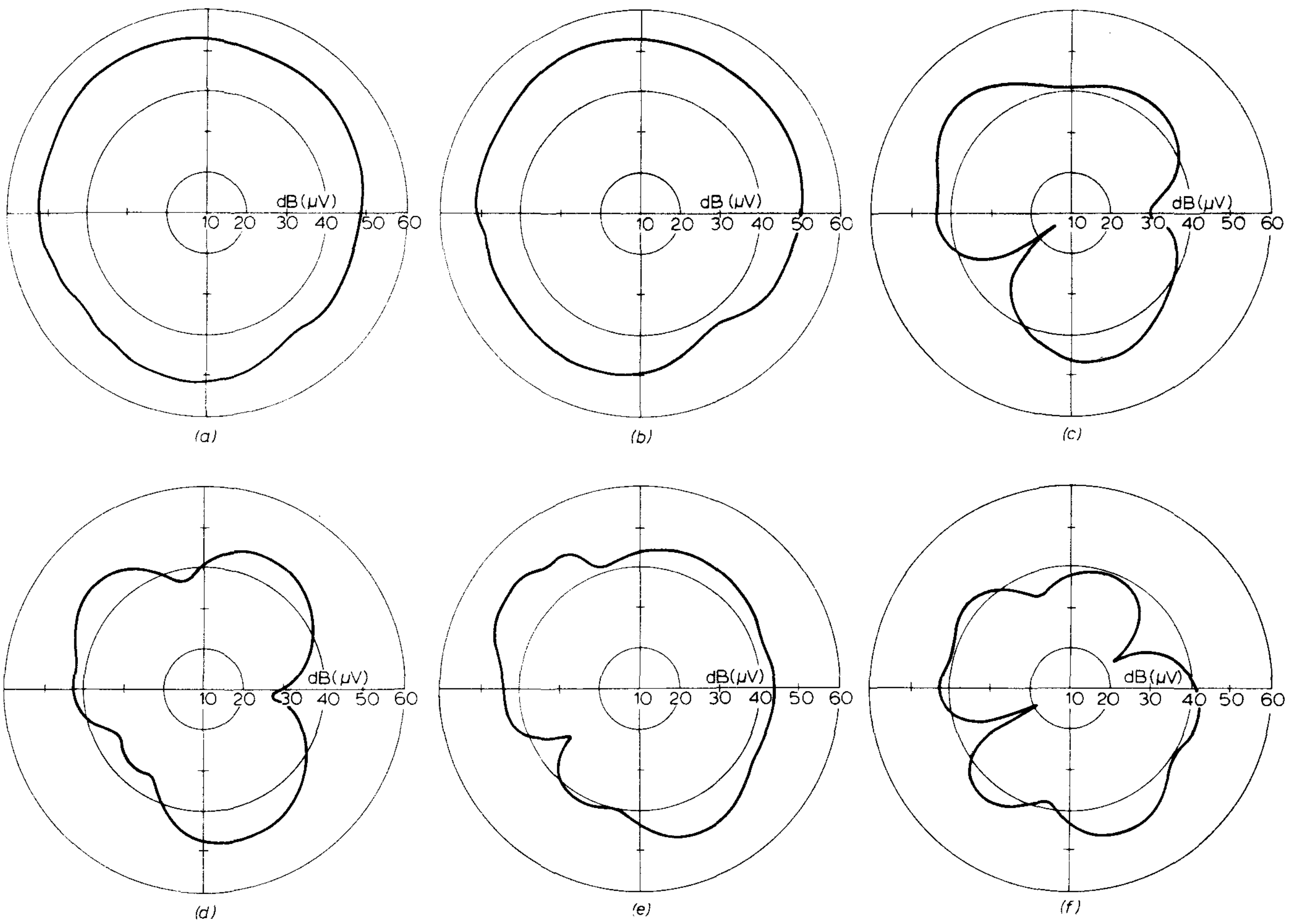
more analytical type in order to evaluate the several factors involved.

2.3.2. Measurements on Car/Aerial Systems

The horizontal radiation patterns (h.r.p.s) of several car aerial systems were measured, using as signal sources the test transmissions from Kingswood and the normal service transmissions from the London area v.h.f. transmitters at Wrotham on 89·1 MHz, 91·3 MHz and 93·5 MHz. Three cars were measured, a Morris 1100 and a Ford Cortina using both their built-in aerials and a detachable aerial and a Wolseley Hornet with the detachable aerial only. The built-in aerials were 1·1 m vertical rods mounted on the offside front wing and the detachable aerial was a 0·9 m near-vertical rod clamped to the roof gutter.

Measurements on the 90·2 MHz Kingswood transmission were made on all the car/aerial combinations with three types of signal, c.p., v.p., and h.p. and with the Morris 1100 a further measurement was made using a c.p. signal with the phase of the v.p. component reversed relative to that of the h.p. component.

The h.r.p.s of the Cortina with built-in aerial are shown in Fig. 1; the results for the other car/aerial combinations were similar in general character. In



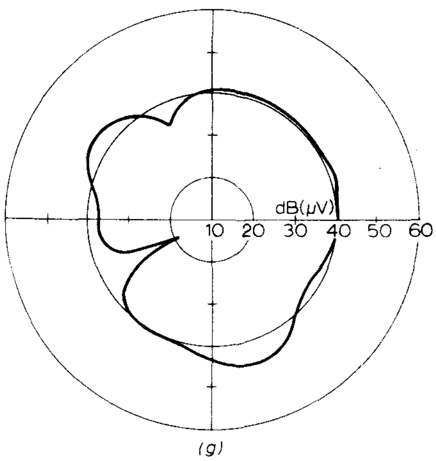


Fig. 1 - Horizontal radiation patterns of Cortina with wing-mounted aerial

(*a*) 90·2 MHz, c.p.
(*b*) 90·2 MHz, v.p.
(*c*) 90·2 MHz, h.p.
(*d*) 92·5 MHz, h.p.
(*e*) 89·1 MHz, h.p.
(*f*) 91·3 MHz, h.p.
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N.B. The diagrams are plotted on a logarithmic voltage scale.

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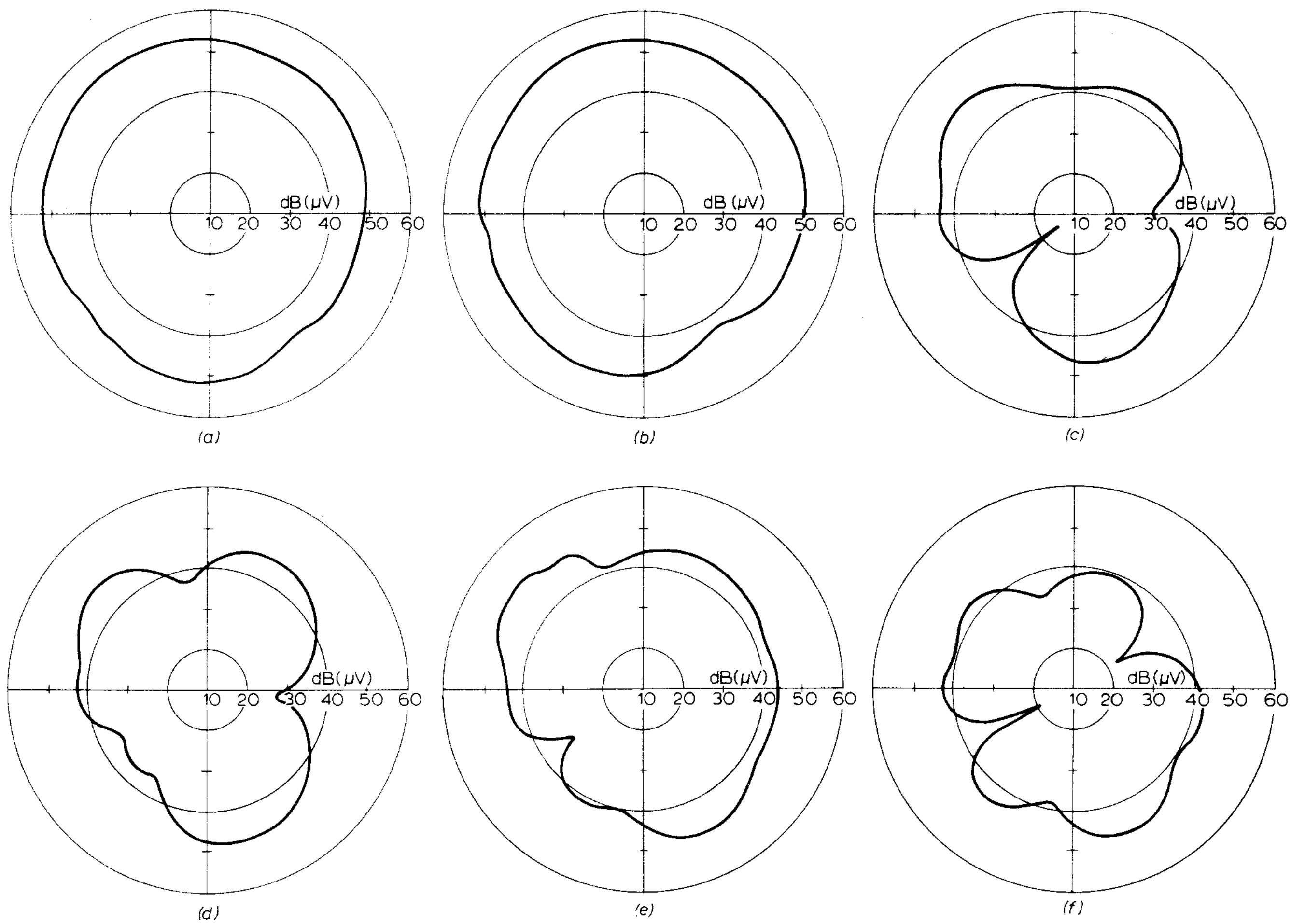

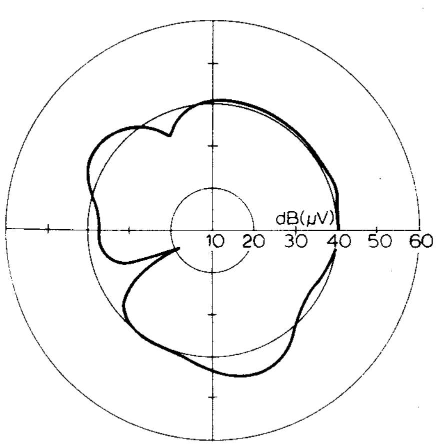

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(*a*) 90·2 MHz, c.p.
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(*f*) 91·3 MHz, h.p.
(*g*) 93·5 MHz, h.p.

N.B. The diagrams are plotted on a logarithmic voltage scale.

TABLE 5

Sensitivity of Car Aerials, in Terms of Mean Output Voltage

	Car	Morris 1100		Ford Cortina		Wolseley Hornet
	Aerial	Wing	Roof	Wing	Roof	Roof
Transmission	Freq. (MHz)	Mean dB (μV)	Mean dB (μV)	Mean dB (μV)	Mean dB (μV)	Mean dB (μV)
H.P.	90·2	41·3 (6·5)*	44·1 (3·8)	41·1 (5·6)	45·7 (4·1)	45·1 (3·8)
H.P.	92·5	42·7 (4·9)	44·9 (4·8)	41·3 (5·0)	47·1 (3·3)	40·2 (5·9)
H.P.	89·1	38·2 (3·2)	41·2 (4·7)	44·0 (3·4)	48·6 (3·2)	45·2 (5·9)
H.P.	91·3	34·4 (6·6)	41·3 (4·2)	39·7 (5·3)	47·3 (3·9)	44·7 (4·7)
H.P.	93·5	40·8 (3·5)	45·2 (4·8)	39·7 (4·4)	47·0 (3·8)	42·4 (5·7)
C.P.	90·2	51·2 (1·7)	52·9 (1·9)	50·5 (1·9)	52·7 (1·9)	51·6 (3·0)
C.P. (Ph. rev.)	90·2	46·1 (3·0)	49·6 (2·1)	– –	– –	– –
V.P.	90·2	49·6 (2·0)	51·3 (1·9)	49·9 (2·3)	51·4 (1·7)	51·7 (3·1)

* Figures in brackets denote the standard deviation of the output voltage.

general, the output voltage was higher and the h.r.p. more nearly omnidirectional with a v.p. or c.p. transmission than with h.p. Table 5 gives the essential features of the measured h.r.p.s in terms of the mean and standard deviation of the output voltage (equivalent o/c voltage from a 75 ohm source) sampled at 5° intervals and normalized to a field strength of 60 dB(μV/m). This refers to the field strength measured at 0·9 m above the surface on which the car is standing and, in the case of c.p. transmission, to the magnitude of the v.p. component. Table 6 summarizes the results given in detail in Table 5.

The ratio of the v.p. to the h.p. component of the nominally c.p. transmission was 6 dB at the site at which the h.r.p.s were measured; also from Table 6, the car/aerial combinations tested were on average 8 dB more sensitive to v.p. than to h.p. Considering c.p. transmission, it would therefore be expected that, at the h.r.p. test site, the h.p. component of the signal would contribute comparatively little to the aerial output voltage. However, from the test results in Table 5 for the Morris 1100 with built-in aerial, it can be seen that the reversal of phase in the c.p. transmission produced a significant change of the mean aerial output voltage. Analysis of the h.r.p.s for this car/aerial combination showed that with the normal transmission phase the v.p. and h.p. contributions to the receiving aerial output were substantially in phase, whereas with reversed phase transmission they were very nearly in phase opposition. This nearly precise phase relationship of 0° and 180° appears to be purely fortuitous, since the effect of the phase reversal is considerably less on the same vehicle with the roof aerial and the differences between the c.p. and v.p. results on the other car/aerial combinations are also generally small. However, it does imply that for a proportion of vehicles the presence of the h.p. component could result in a significant degradation of performance on c.p. transmission as compared with that on a pure v.p. transmission.

TABLE 6

Summary of Car Aerial Sensitivity Measurements in Terms of Mean Output Voltage, dB(μV)

Transmission	Wing Aerials	Roof Aerials	All Aerials
H.P.	40·3 (4·8)*	44·6 (4·5)	42·9 (4·6)
C.P.	49·6 (2·1)	51·8 (2·3)	50·9 (2·2)
V.P.	49·7 (2·1)	51·5 (2·2)	50·8 (2·2)

* Figures in brackets denote the standard deviation of the output voltage.

Considering h.p. transmission, the h.p./v.p. ratio of the nominally h.p. signals at the h.r.p. test site was between 15 dB and 17 dB. Allowing for the h.p./v.p. sensitivity ratio of the car aerials, it appears that the h.p. component of the signal made the major contribution to the receiving aerial output but that of the v.p. component was not negligible. The presence of this appreciable v.p. component, randomly phased relative to the h.p. component, may account in part for the more irregular shape of the h.p., h.r.p.s and the large variations in aerial sensitivity with frequency.

2.3.3. Measurements of Field Strength at 0·9 m a.g.l.

Measurements were made of the field strength at 0·9 m a.g.l. of the h.p. and v.p. components of the fields produced by the h.p. and c.p. test transmissions at a total of 55 sites chosen at random in three areas approximately 14 km from the transmitter. The three areas were a small town, a 2 km stretch of rural road in flat terrain and a 2 km stretch of rural road in undulating terrain, and were spaced over a total distance of about 8 km. Ground profiles of the propagation path for two points near the extremes of this 8 km range are shown in Figs. 2 and 3. The sites were chosen as representing three common types of local environment and also as being typical of the general case where the propagation path is obstructed by terrain features. The results are shown in Table 7. For the purpose of analysis, the fields other than HP/H are expressed relative to the HP/H field; the standard deviations, however, indicate the range of variation of the absolute field strengths over the area

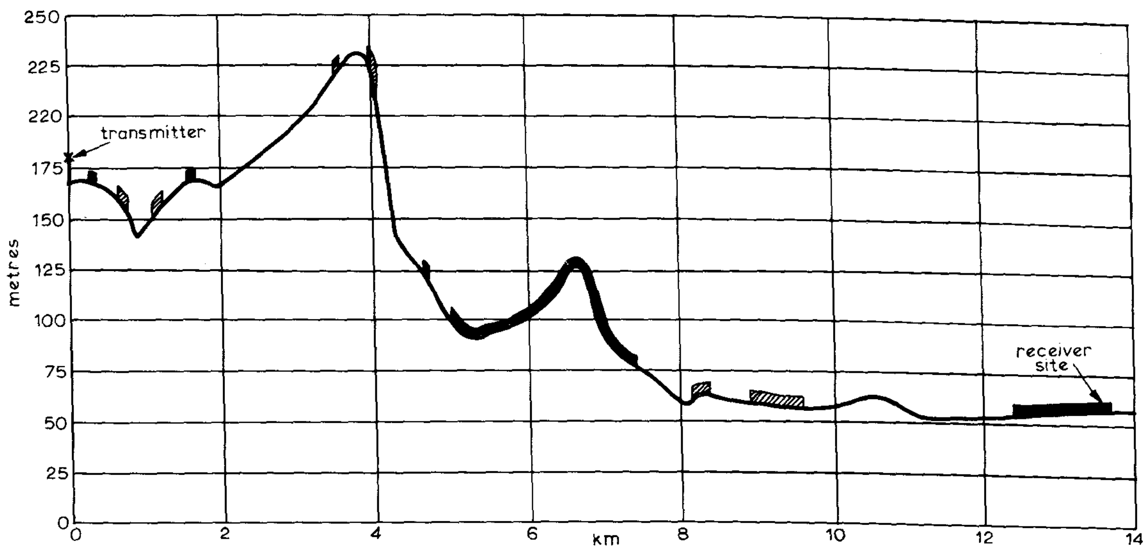


Fig. 2 - Ground profile

Houses Trees (Heights not to scale)

4/3 Earth Radius. Scale Ratio: 1:26.4

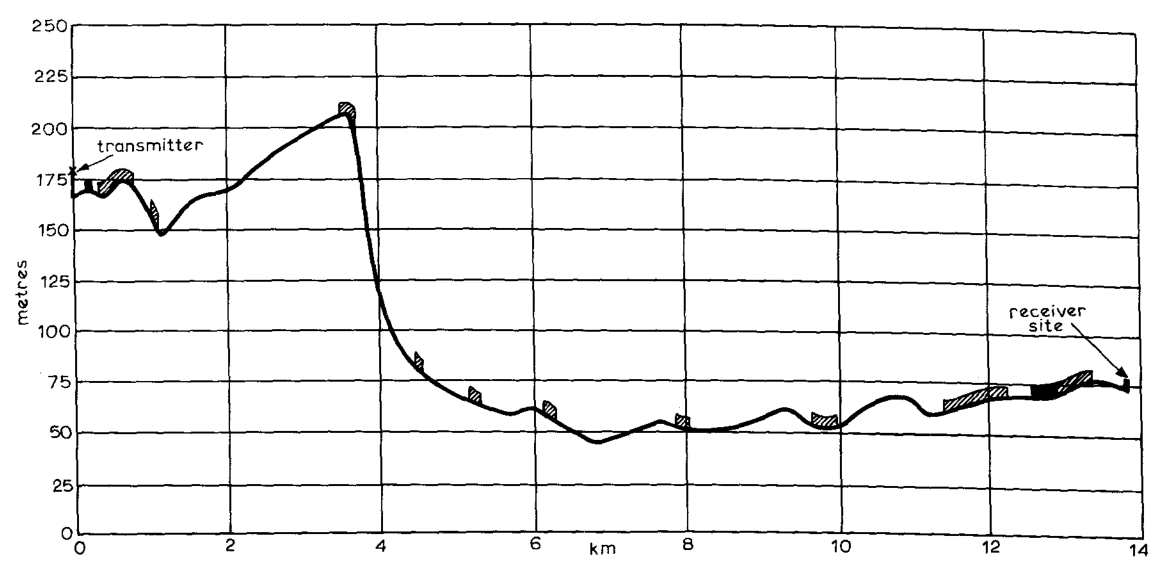


Fig. 3 - Ground profile

Houses Trees (Heights not to scale)

4/3 Earth Radius. Scale 1:26.4

TABLE 7

Relative Mean Field Strength of Test Transmissions at 0·9 m a.g.l., normalized to mean value of HP/H (55 sites)

	HP/H Std. dev. dB	HP/V / HP/H Mean dB	HP/V Std. dev. dB	CP/H / HP/H Mean dB	CP/H Std. dev. dB	CP/V / HP/H Mean dB	CP/V Std. dev. dB
Town	4·8	−15·2	5·0	−0·8	5·2	−6·0	6·0
Road in flat terrain	7·5	−8·5	5·8	−3·0	6·6	−3·5	6·6
Road in undulating terrain	7·4	−6·8	4·5	−1·0	6·4	+0·5	6·7
Mean of all areas	6·6	−10·2	5·1	−1·6	6·1	−3·0	6·4

of investigation.

The standard deviations of the ratios of the h.p. to the v.p. component of the fields produced by the h.p. and c.p. transmissions are also of interest, these are shown in Table 8.

The average v.p./h.p. ratio for the c.p. signal at 0·9 m a.g.l. shown in Table 7 is considerably lower than would be expected from theoretical considerations.[1] Measurements of field strength made a few hundred metres from the c.p. transmitting aerial at a site with a clear line-of-sight propagation path gave a v.p./h.p. ratio of 10 dB, which agrees closely with the theoretical prediction. Similar measurements at sites approximately 3 km from the transmitter, with propagation paths obstructed only by trees, gave ratios varying between 1·5 dB and 6 dB. The ratios of the mean field strengths in the three areas shown in Table 7 varied from −5·2 dB to 1·5 dB. It thus appears that the full theoretical advantage of v.p. at low receiving aerial heights is only realized with ideal receiving sites. There is a marked similarity between the overall mean results shown in Table 7 and those for the indoor measurements shown in Table 3; this indicates that there is a considerable degree of depolarization close to ground level even in the open air.

2.3.4. Discussion of Results of Car Radio Measurements

From the results given in Tables 6 and 7 an overall figure of merit can be derived for each type of polarization as:

$$G = S + E - \sqrt{\sigma_S^2 + \sigma_E^2}$$

where S = sensitivity in dB
E = relative field strength in dB
σ_S = standard deviation of sensitivity in dB
σ_E = standard deviation of field strength in dB

TABLE 8

Standard Deviation of Ratio of H.P. to V.P. Component of Field at 0·9 m a.g.l. (55 sites)

	Standard Deviation, dB
HP/H / HP/V	6·4
CP/H / CP/V	5·9

The basis of this method of calculation is that the quality of service when the signal input to the receiver is fluctuating rapidly is determined chiefly by the quasi-minimum signal level.

The merit of c.p. relative to h.p. is indicated by $G_c - G_h$; a positive value denotes a superiority of c.p. over h.p. and a negative value the reverse.

For h.p. transmission, the relative field strength E is that of the major component HP/H. For c.p. transmission it is CP/V since, although this is the minor component of the field, it makes the major contribution to the receiving aerial output.

In this connection it is apparent from Table 7 that the components of field making the minor contribution to the aerial output, namely HP/V in the case of the h.p. field and CP/H in the case of the c.p. field, are relatively larger at the field measuring sites than at the h.r.p. test site. It is therefore pertinent to ask whether the sensitivity figures obtained from the h.r.p. measurements are applicable for deriving a figure of merit in the typical situation on the road.

On the assumption that the relative phases of the contributions of the h.p. and v.p. components of the field will vary randomly, depending on the geometry of the car/aerial system and the local configuration of the r.f. field, an increase in magnitude of the minor contribution will have two effects. It will increase the mean value of the apparent sensitivity S; it will also increase the standard deviation σ_S and in general the increase of σ_S will be greater than that of S. The equation proposed for deriving the factor of merit G is such that these changes tend to be self-cancelling, it will therefore be assumed that the use of the values of sensitivity obtained from the h.r.p. measurements will not introduce any major error, bearing in mind the wide range of variation of all the quantities involved.

Carrying out the calculation for wing-mounted and roof-mounted aerials separately, we find the superiority of c.p. over h.p. to be:

Wing aerials: 7·8 dB
Roof aerials: 5·4 dB

The present practice in the U.K. is that the great majority of car radio installations employ wing-mounted aerials. In determining the average improvement in car radio reception that would result from a change from h.p. to c.p. we are therefore justified in taking a figure closer to that for wing aerials than for roof aerials, say 7 dB.

2.4. Reception in the Open Air with Portable Receivers

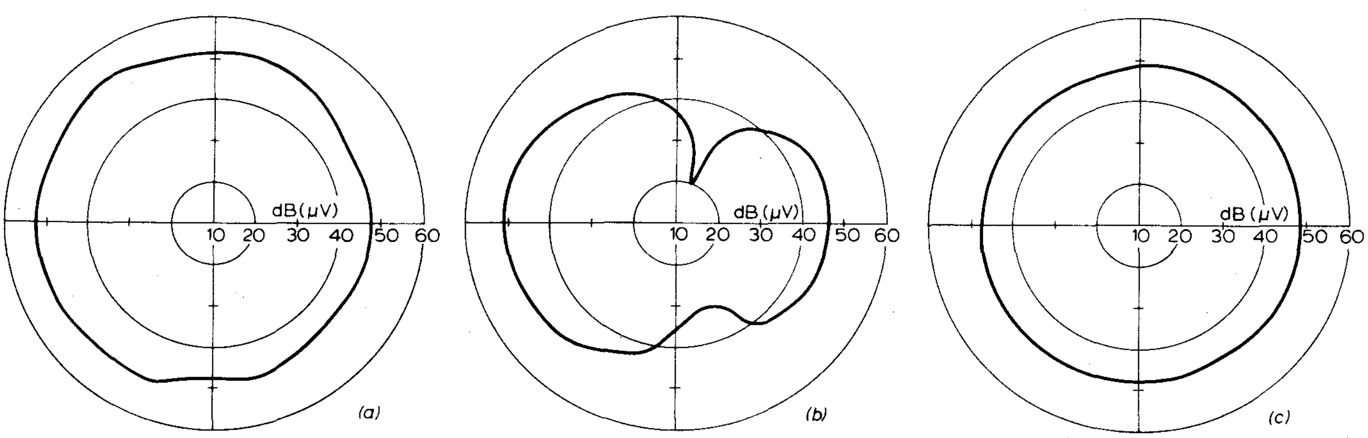
It was assumed that the most frequent use of receivers falling into this category was in the typical 'picnic' situation with the receiver standing on the ground. Measurements were therefore made to determine the h.r.p. of a portable receiver and the field strength of h.p. and c.p. transmissions at 0·3 m above ground level.

2.4.1. Measurements of Portable Receiver Aerial Characteristics

Only one receiver was used for these measurements, a British transistor portable approximately 330 mm x 190 mm x 100 mm with a 750 mm extending rod aerial for v.h.f. reception which could be rotated to either a vertical or horizontal position. The great majority of current v.h.f. portables, apart from the very small 'personal' models, are of similar physical size and would presumably give similar results as far as their aerial characteristics are concerned.

H.R.P.s were plotted with the receiver standing on the ground, with the aerial rod first vertical and then horizontal, using the Kingswood transmitters as signal sources. The results are shown in Fig. 4, normalized to a field strength of 1 mV/m for the major component of the field. The h.p./v.p. ratio of the nominally h.p. signal at 92·5 MHz was 4 dB and of the nominally c.p. signal at 90·2 MHz was −26 dB.

Considering the h.r.p.s for a h.p. transmission, Fig. 4(*a*), the pattern with the aerial vertical is fairly omnidirectional with a maximum/minimum ratio of 7 dB, while Fig. 4(*b*), the pattern for a horizontal aerial, closely resembles a cosine diagram with two fairly deep minima. The asymmetry of both patterns is



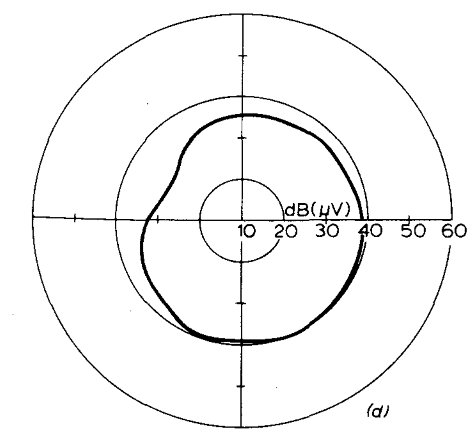


Fig. 4 - Horizontal radiation patterns of portable receiver

(*a*) Aerial rod vertical, 92·5 MHz
h.p. field 64 dB (μV/m), v.p. field 60 dB (μV/m)
(*b*) Aerial rod horizontal, 92·5 MHz,
h.p. field 60 dB (μV/m), v.p. field 56 dB (μV/m)
(*c*) Aerial rod vertical, 90·2 MHz,
v.p. field 60 dB (μV/m), h.p. field 34 dB (μV/m)
(*d*) Aerial rod horizontal, 90·2 MHz,
v.p. field 60 dB (μV/m), h.p. field 34 dB (μV/m)

N.B. The diagrams are plotted on a logarithmic voltage scale.

probably due to the contribution of a component of field in a direction orthogonal to that of the aerial. Taking into account the relative lack of directional effects with a vertical aerial and the fact that a vertical aerial is generally considerably more convenient and less obtrusive, it is likely that listeners will tend to prefer to operate their receivers with the aerial vertical. It also appears from Figs. 4(*a*) and 4(*b*) that, unless the ratio of the h.p. to the v.p. component of the field in the vicinity of the receiver exceeds about 6 dB, a vertical aerial will be at least as efficient as a horizontal one.

Figs. 4(*c*) and (*d*) illustrate the performance on a nominally circularly polarized transmission at a particular location where the v.p. component of the field is much greater than the h.p. component. It will be seen that the pattern for the vertical aerial is almost completely omnidirectional. With the aerial horizontal there is little resemblance to Fig. 4(*b*) and it appears that the receiver is still responding primarily to the v.p. component of the field but with an efficiency some 10 dB lower.

2.4.2. Measurements of Field Strength at 0·3 m a.g.l.

Owing to the low power and restricted aerial height of the Kingswood transmitters it was not possible to make satisfactory measurements of their field strength at 0·3 m a.g.l. at the more distant or poorer receiving sites. The required information was therefore obtained indirectly by applying a correction for height gain to the figures for field strength at 0·9 m a.g.l. set out in Table 7.

The height-gain correction applying to h.p. transmissions was obtained from measurements of the Wrotham transmissions made at 16 sites at distances between 25 and 30 km from the transmitter. These sites varied in type from urban to open rural country. At each site, measurements were made of the h.p. and v.p. components of the field for each of the Wrotham transmission frequencies.

The corresponding measurements for c.p. were made on the Kingswood transmission at 4 sites approximately 3 km from the transmitter. These sites were all rural in type and had propagation paths unobstructed by terrain.

The resulting figures for field strength at 0·3 m a.g.l. are given in Table 9.

TABLE 9

Relative Mean Field Strength at 0·3 m a.g.l.

Component of Field	Relative Field Strength, dB
HP/H	0
HP/V	−1·9
CP/H	0
CP/V	+3·6

JMP

2.4.3. Discussion of Results of Portable Receiver Measurements

It was established in Section 2.4.1. that, provided the h.p./v.p. ratio of the received signal is less than about 6 dB, a portable receiver will generally operate more efficiently with a vertical than with a horizontal aerial. Also the absence of directional effects and considerations of convenience tend to encourage the use of a vertical aerial. From Table 9 it is seen that at an average site the h.p./v.p. ratio is less than 2 dB; the comparison between h.p. and c.p. transmission can therefore be made by comparing the magnitudes of the v.p. components of field at 0·3 m a.g.l. which they produce. Table 9 shows that the result of a change from h.p. to c.p. would be equivalent to an increase in transmitter power of between 5 dB and 6 dB.

3. CONCLUSIONS

For reception in the home, the effect of a change from horizontal to circular polarization would range from the equivalent of a reduction of transmitter power of 3 dB for listeners using outdoor aerials at roof level to an increase of 1 dB for listeners with portable receivers on the ground floor.

For car radio reception the effect would be equivalent to an increase of transmitter power of about 7 dB and for reception by portable receivers in the open air, to an increase of 5 to 6 dB.

These results are calculated for the case where the total effective radiated power is the same for c.p. and for h.p., i.e. the power radiated in the h.p. component is reduced by 3 dB when the v.p. component is added.

It must be emphasized that the results given above are statistical averages and that, particularly with car radio and portable receivers where the results depend greatly on the degree of depolarization of the signal or on particular aerial characteristics, there will be considerable variations in individual cases. Furthermore, this investigation has been concerned only with signal level. There may be other consequences of a change in polarization, such as an increase in the incidence of multipath propagation, which could affect the overall result by increasing the possibility of audible distortion of the programme occurring.

4. REFERENCE

1. Field strength near the ground at v.h.f. and u.h.f.: theoretical dependence on polarization. Research Department Report No. 1969/3 (RA-32).

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